Experiment Research on Electrolytic Truing and Dressing of Aluminum Bonded Grinding Wheel

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Keywords: Aluminum alloy-bonded wheel. Diamond wheel. Electrolytic. Truing. Dressing

Abstract. Metal bonded wheels are widely used for grinding hard and brittle material due to their high bonding strength, good wear resistance and the ability to absorb heavy load during grinding. An aluminum alloy-bonded diamond wheel was developed by using lost foam casting method for grinding hard and brittle materials such as engineering ceramics. The cast blank of the diamond wheel must be truing and dressing to maintain good sharpness and grinding performance. An electrolysis equipment was developed for truing and dressing the wheel by electrolytic method. Electrolytic parameters were also determined through step-by-step experiment. Cylindricality error of the wheel was controlled in 8 micrometers after truing, and exposed height of the abrasive particles reached a predetermined requirement after electrolytic machining.

1 Introduction

Metal bonded wheels have the characteristics of high bonding strength, good wear resistance and ability to absorb heavy load during grinding. They are widely used for grinding hard and brittle material [1]. A new type of aluminium alloy-bonded diamond wheel was developed by using lost foam casting method [2, 3] for grinding hard and brittle materials such as engineering ceramics. Truing and dressing are necessary for the cast blank of diamond wheel to maintain good sharpness and grinding performance. Metal-bonded wheels are poor in self-sharpening and easy to be clogged, thus will increase grinding force and affect the stability of the grinding process and even the quality of the workpiece’s surface. So the wheels must be dressed frequently during grinding. Metal bond wheels are difficult in truing and dressing due to their high mechanical strength. The high-efficiency and high-quality dressing technology of metal-bonded wheels has become a key technology for precision and high-efficiency grinding. Scholars from various countries have developed new dressing technologies for metal-bonded wheels, including electric spark dresser, cup-shaped silicon carbide grinding wheel dresser, soft elastic dresser, laser dresser and electrolytic dresser [4-8]. Compared with other methods, dressing wheels by electrolytic machining has advantages for metal-bonded wheels because no deformation occurs during the processing and it has nothing to do with the mechanical properties of the metal material. Aluminium alloy can be electrolyzed. So electrolysis can also be used to truing and dressing aluminum alloy-bonded diamond wheels. An electrolysis equipment which used for both truing and dressing was developed in this paper. Parameters for truing and dressing the aluminium alloy-bonded diamond wheel were also determined through step-by-step experiments.

2 Develop the electrolysis equipment

The experimental equipment consists of supporting equipment, power supply, electrolyte and recycling filtration system. A SMD-30 CNC double pulse plating power supply was used for truing and dressing in this paper. It provides periodic reverse pulse current in millisecond, the length of the positive pulse and reverse pulse can be adjusted individually. Damage by continuous arc discharge can be avoided when using a high-frequency pulse plating power supply in electrolytic. At the same time, numerical control can be used to maintain a stable electrolytic process. Wheel carriage, transmission mechanism, electrode and gap adjustment are respectively fixed on the supporting equipment. The wheel mounted on wheel carriage as shown in Fig.1. The equipment is shown in Fig. 2.

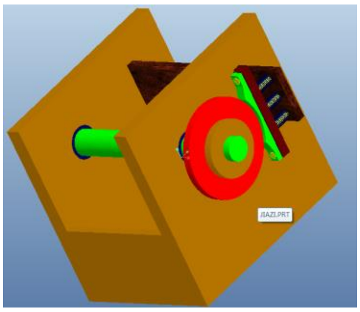


Fig.1 Equipment schematic

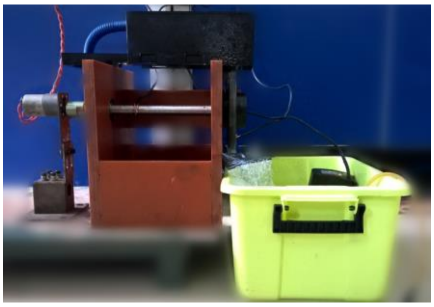


Fig.2 electrolysis equipment

The power supply is connected to the shaft with a wire and conduct the wheel as an anode. The cathode is generally made up of conductive copper or stainless steel [9]. Stainless steel was used for cathode in this paper, shown in Fig. 3. The radius of the arc in the middle is according to the diameter of the wheel that is to be electrolyzed. The arc length is one-sixth circumference of the wheel. The width of the electrode is 12mm, about 2 mm wider than the width of wheel which is 10mm. The surface of the electrode has been polished. Both sides of the electrode which connect with the arc are inclined to facilitate the flow of the electrolyte into the gap, and can protect the connectors (bolts) which assembled on the cathode from being corroded by electrolysis. The properly design of the cathode makes the conductive area as large as possible, the electrolyte can smoothly and evenly flows through the gap during electrolyzing.

The stainless steel cathode fixed on the supporting together with insulation plate, screws and springs. Keep the gap between cathode and the surface of wheel in 0.5~1.5mm by rotating the nut and ensure the cathode insulated from equipment. The size of the gap can be adjusted at any time by the adjusting device as shows in Fig.4.

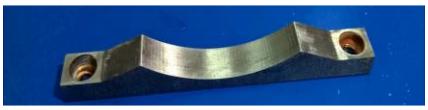


Fig.3 Stainless steel cathode

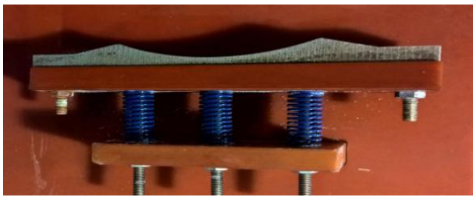


Fig. 4 adjusting device

The wheel mounted on the shaft and driven by a rotating motor through a couple. The coupler coated with insulating layer so that the wire of positive pole from power supply does not affect the operation of the motor which connected to the shaft. Motor speed can be adjusted in the range of 0～120r/min.

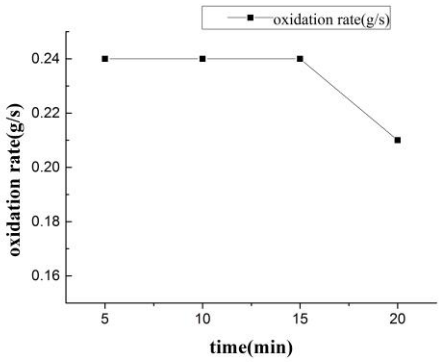
3 Experimental research on electrolysis aluminium alloy-bonded wheel

Experimental researches include truing and dressing. Truing is to remove the material from the surface of the wheel and control the cylindricality error. The material layer removed by electrolysis is relatively deep. The calendric error of the grinding wheel is 58μm before electrolysis, and it will be reduced to 10μm by electrolytic truing. The dressing of wheel is to expose abrasive grains by removing a small amount of bond from the surface of the wheel. The goal is controlling the exposed height of abrasive to one-third of the diameter of the diamond grit.

3.1 Experiment study on electrolytic parameter

All experiments were carried out with 12% sodium nitrate solution as electrolyte. The optimum electrolysis time, current value and electrolytic gap size were investigated by experiments.

Electrolysis experiments results with current of 2 amps and electrode gap of 2 mm are shown in Fig. 5. It can be seen that material removal rate keep constant in 0.24g/s when electrolysis time is less than 15 minutes. But the electrolysis rate decreases rapidly after electrolysis for 15 minutes. The average material removal rate decreased to 0.21g/s after electrolyzed for 20 minutes. The reason is aluminium oxide film formed on the surface of the workpiece will deteriorate the electrolysis process. Then the oxidation rate in electrolysis decreases with the increase of electrolysis time. Therefore, it is necessary to remove the oxide film from the surface of the workpiece after the electrolysis time reaches 20min.



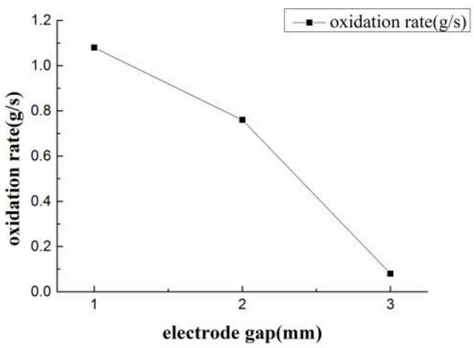


Fig. 5 oxidation rate change with time   Fig. 6 oxidations rate change with the size of gap

Electrolyzed for 15 minutes with electrolysis gap of 2mm and current of 0.5, 0.75, 1, 1.5, 2, 2.5, 3 and 4 amps respectively. The result shows that material removal rate increases with the increase of current. However the generating speed of oxide film was also accelerated with the increase of current. When the oxide film reaches a certain thickness, it will affect the process of electrolysis. Although there was a filtration cycle system, the solution still appeared muddy, and aluminum hydroxide was produced. Therefore, the current value should not be too large.

Another experiment was carried out with the current of 2 amps, electrolyzed for 15 minutes with different electrode gaps. Experiment results are shown in fig. 6. It can be seen that the electrolysis rate decreased rapidly with the increasing of electrode gap. Therefore, from the perspective of improving electrolysis efficiency, the electrode gap should be kept as small as possible. On the other hand the gap must be large enough to easy flow the circulating electrolyte.1 mm electrode gap was choired in the following experiments.

3.2 Experiment on truing grinding wheel by electrolysis

In the experiment, an aluminium alloy-bonded grinding wheel without abrasive grit was used for the test. The material of the wheel is the same as that of the aluminium alloy-bonded diamond grinding wheel developed by lost foam casting method. According to the previous experiment results, 12% sodium nitrate solution is provided for electrolyte, and the electrolytic gap is 1 mm. By changing the electrolysis time, current value and wheel rotating speed, the experiment researches on truing wheel were carried out step by step. The aim is to decrease cylindricality error from 58μm to less than 10μm.

Firstly, the grinding wheel was assembled on the electrolysis equipment. Electrolytic current is 1A; motor speed is 50 r/min, electrolyzed for 10 minutes. It could be seen intuitively that the oxide film generated by electrolysis on the surface of grinding wheel was very thin and distributed unevenly after electrolysis. The cylindricality error of the wheel decreased to 51μm. Therefore, it could be judged that the electrolytic current and time were not large enough. So to rapid reduce the cylindricality error of the wheel need a larger current and longer electrolytic time.

On the basis of above, the wheel was electrolyzed the second time with the current of 2A after removed the oxide film from the surface of the wheel. Experiment result showed that the average removal rate of material thickness was about 0.275μm/min, and the cylindricality error of wheel decreased to 40μm. The cylindricality error of the wheel was still large. So the electrolytic parameters should be increased in the following electrolytic processing.

The electrolysis experiment of third step was carried out again with the electrolysis current of 3A and the speed of motor was reduced to 30r/min. The cylindricality error decreased to 22μm after truing 45 minutes. From these experiments, it reveals that not only current affects truing speed, but also rotational speed affects truing speed. Since the wheel has a certain rotational speed and the arc length of the cathode is only 1/6 of the circumference of the wheel, the truing efficiency of the grinding wheel can be improved by selecting a suitable electrolytic current, electrolysis time and wheel speed. When the cylindricality error is large, the electrolytic truing rate can be relative high by selecting current of 3A and electrolysis for a longer time with wheel rotational speed in 30 r/min.

The fourth step of electrolysis experiment was carried out with electrolytic current in 2A, wheel rotational speed of 30 r/mi and electrolyzed for 20 minutes. Cylindricality error of the wheel was down to 14μm. A more even oxide film on the surface of the grinding wheel can be found after experiment.

The fifth and the last step of electrolysis experiment was carried out with electrolytic current of 2 amps, wheel rotational speed of 30r/minutes and electrolyzed for 15 minutes. Cylindricality error of the wheel decreased to 9μm, which meet the requirement. The truing by electrolytic method took 5 steps for 95 minutes in total.

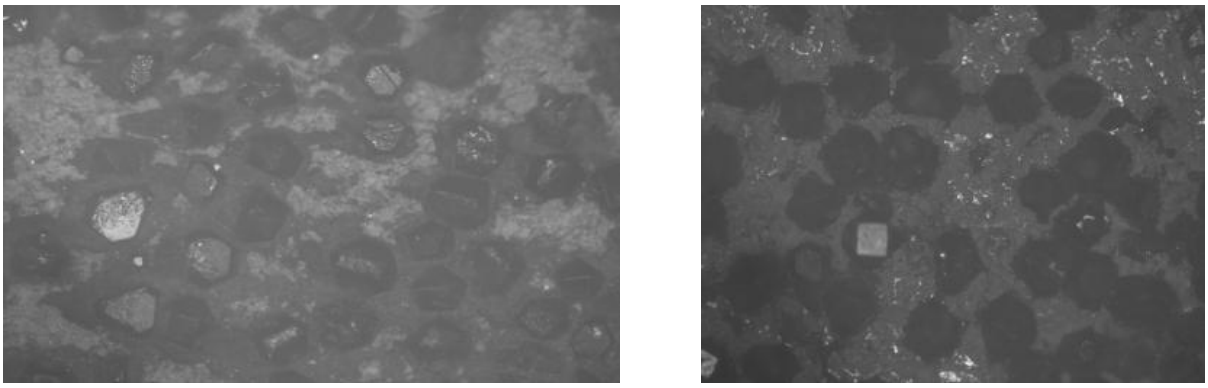
3.3 Experimental study on dressing aluminum bonded wheel by electrolysis

Dressing grinding wheel by electrolysis method is to expose abrasive grains by removing a small amount of bond from the surface of the wheel. The aim of dressing is to control the exposed height of abrasive reach one-third of diameter size and ensure there is a certain debris space between the abrasives. So the cutting edge outside the protruding binder of abrasive can reach the best cutting edge height. The grit size of the diamond abrasives on the new type of wheel is 50/60. The diameter of diamond abrasive is about 250/300μm. The best cutting edge height is one-third of diameter size of the abrasive grain, should be about 85μm.

Eight areas on the circumference of the grinding wheel were taken microscopic photo after each step of electrolytic experiment and compared with the previous one. Then adjust the electrolytic parameters step by step. After each step of electrolysis, the appearance of oxide film on the surface of wheel was observed. The same zone was also taken photos by microscope to observe the exposure changing of abrasives after removing the oxide film. Then continued dressing until it reached the desired edge height.

Fig.7 surface of the wheel before electrolysis

Figure 7 shows the surface of the grinding wheel before electrolytic dressing. The experimental electrolysis on grinding wheel was carried out with sodium nitrate solution of 12% as electrolyte, electrolytic gap of 1mm, electrolysis time of 10 min, rotational speed of grinding wheel of 100r/min, current of 1A. Black and not evenly distributed oxide film formed on the surface of the wheel can be seen by microscopic, and some zones didn’t be electrolyzed also can be seen. Therefore, the wheel was dressed for the second step with electrolytic current in 2A; rotational speed of the grinding wheel kept at 100rpm. It can be found from Fig.8(a) that the oxide film on the wheel became more evenly, and most of the grains exposed out of the binder after 20 minutes processing. But obviously the height of exposures didn’t enough.



(a) Second electrolysis (b) fourth electrolysis

Fig.8 grinding wheel surface micrograph

The electrolysis current was 2A, the average exposure height of the abrasives increased to 65μm after electrolyzed 30 minutes. The surface was shown in Fig.8 (b) after another 30minutes electrolysis and removed oxide film from the wheel, the bonding of the abrasive and the surrounding metal bonding agent was still in good condition, and the oxide film on the surface of the wheel was well removed. The exposure height of the abrasives was about 80μm.

Finally, reduced electrolysis current to 1A, and electrolyzed for 15 minutes to finish the final dressing. The final surface shows in Fig. 9, and the micrograph of abrasive shows in Fig.10.

It took five steps and105 minutes in total to finish the dressing experiment of aluminium alloy-bonded diamond grinding wheel. This efficiency dressing method meets the required precision without stress damage to the wheel.

Fig.9 final surface of wheel

Fig.10 micrograph of abrasive

4 Conclusion

Electrolysis equipment was developed for truing and dressing a new type of aluminium alloy-bonded wheel which developed by lost foam casting. Truing was conducted in five steps, which took 95 minutes in total. The cylindricity error of the wheel is controlled in 8μm. The aluminium alloy-bonded diamond grinding wheel with diamond abrasives in 50/60 grit size was dressed by five steps, and the abrasive got the best exposure height after dressing for 105 minutes in total. The appropriate parameters for dressing and truing this type of wheel by electrolytic method were obtained. And the truing and dressing result conforms to the expectation.

Acknowledgements

This work was financially supported by "National Nature Science Foundation of China" (No.51375180) 、 (No.51175192) and "Science and technology plan project of Quanzhou" (Z1624059)

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